The First Montague Deep Energy Retrofit

WHY do Green (or) Net Zero Energy Ready (or) Passive Haus

Background

Making your way into Retirement one of the biggest decisions that needs to be made relates to identifying the type of home you are likely to enjoy the most as well as a desirable location for that home. This can be a difficult decision, particularly if you have lived in many different cities and housing situations during your career. For us, this included the full range of housing found in Canada ranging from apartments and townhouses in Montreal Quebec to suburbia in Oakville Ontario and Winnipeg Manitoba. Along the way we lived and worked overseas four different times and have seen firsthand many different ways of living.

Objectives

The first thing my wife and I did was to sit down and establish the key objectives we should select as a guide through this journey. For many different reasons these objectives turned out to be;

1) The location would be Winnipeg
2) Any investment of time and money in a house should be durable, resilient, comfortable, and be in a walk-able community
3) We wanted to live in the home for as long as possible in our retirement
4) Make decisions with a view to reducing our carbon footprint on the world through reducing ongoing carbon consumption while utilizing local labour and materials to the extent that is practical.

This first objective meant that our initial attention had to focus upon attractive communities within Winnipeg. Though we had lived in Winnipeg longer than any of the other dozen places we had lived, we had at least one in mind. Two of our children had lived in several walk-able communities that looked attractive to us – but finding an available residential lot on which to build a new house proved to be nearly impossible. So our search turned to finding an existing house that could satisfy our needs, either through renovation or replacement.

Additional Criteria for Success

To achieve the objectives we had set for ourselves we needed specific criteria that could be used to compare choices in ways that would help us achieve those objectives. With respect to the house and location the following criteria were important:

- Main floor bedroom and all necessary facilities to allow for life with limited mobility on the main floor of the house.
- A significant vegetable and flower garden, something we had always worked towards but never achieved.

- Just enough space to accommodate our most important hobbies; and
- Offer walk-able distances to a grocery store, public library, coffee shop, and bus service with good service to the heart of the city.

Renovation and/or construction considerations included the desire for a building that would:

- Be resilient to changes in the environment, this could include even more extreme weather conditions than Manitoba already experiences. (Also see http://www.climateatlas.ca/ for analyses of very long range forecasts of what we may experience in the future)
For your reference, key environmental design conditions for Winnipeg are approximately:
For peak heating demand PHPP uses an average -17 C for the highest demand month the winter. ASHRAE specifies about 5600 heating degree days for design. Typical design temperature for insulation is -36 C. Record low temperature is -48 C.
For peak cooling demand, PHPP uses an average +20 C for the highest demand month in the summer with a daily temperature swing of 12 C. Approximately 180 cooling degree days is often used for traditional ac design. Record high temperature is 47 C.)
- Require little on-going maintenance (do it once and do it right)
- Offer low on-going operating cost (reduce exposure to escalation in energy costs)
- Allowed migration to Net Zero Energy (a means of mitigating escalation in electrical energy costs).

Location and House Selection

When you have a reasonably good idea of what you are looking for in a house the process is familiar to most people. Watch real estate sites, talk to friends, drive by candidates, ride bikes in the neighbourhood and develop a sense of value/cost in the marketplace. We found bike riding through candidate areas to be a good method to get a better sense of the walking environment, ambient noise levels and air quality. This is very effective as it can even identify differences between parallel streets or one end of a block to another in terms of ambient noise levels. It also allows an assessment of crossing safety at nearby busy streets and rides down back alleyways can be very revealing.

While all this was in progress I had the opportunity to attend a one week Passive House Design course being presented in Winnipeg, presented by Passive House Canada in association with Sustainable Building Manitoba. This was a great opportunity to get an inside look at the details of Passive House design so that I could determine for myself if it offered anything practical for us in our quest. For an Engineer with post-graduate training in Building Science this was a great investment. Not only did I gain an understanding of what it took to build a modern high efficiency building, but I was introduced to important fundamental analytical tools (like WUFI for moisture permeability, THERM for thermal performance and PHPP for overall building performance). Beyond that, I met experienced contractors with interests that paralleled my own which proved to be invaluable. Sun Certified Builders Cooperative had been building homes for many years and among the first to build R2000 homes in Manitoba. They did not stop there but continued to improve techniques and overall building performance with each building. The standards set by Passive House International became a new objective – but they, like me, were unsure that it would be practical to meet these standards in the Manitoba climate. The fact that few PHI-certified components are available in Canada at realistic prices was a significant concern – things like windows, doors, and mechanical equipment. Nevertheless, the course did help with refining construction technique and provided background that would be valuable for future buildings.

The New To Us House

About six months after taking the design course, we identified a good candidate house and proceeded to make the purchase. The foundation of our new house was to be a post-war story and a half building built in 1947 on a standard residential lot (50 ft by 120 ft). The size of the house was 800 square feet on the main floor and 400 square feet on the second floor and it was sitting on a foundation with a basement. Other than a face-lift in about the early 1970's it had not been renovated to any significant extent and it was located in an area that met our criteria. Views of the outside of the home follow.

There were no signs of significant cracks in walls or the foundation that would have warned us away from the building. Along with its location, the area is served by a combined sanitary and storm sewer. We knew we would have to install a sewer backflow valve and sump pump to provide the minimum level of protection from water in the basement.

After possession of the home, a closer look at the concrete floor indicated that, rather than fix and patch for the required plumbing upgrades, it would be better to replace the whole floor while the basement was empty. The basement was clearly damp, not helped by the installation of a first generation high-efficiency furnace combined with a well sealed basement and no ventilation. Clearly, if we were to follow the rule of do it once and do it right, then that meant applying some of the Passive principles from the outset. Start digging to replace all the sub-grade plumbing and old weeping tile system. Keep digging and put insulation under the floor – if this source of heat loss was not dealt with there was no hope for meeting our eventual objectives. Gutting the basement and carrying out this upgrade would be the first step in the process. Fortunate for us, by the time we were ready to start winter had arrived and outdoor construction work was slowing down. It was time to engage our friends at Sun Certified Cooperative Builders to start work on our project house. It would be dirty and muddy, but it would be inside.

The Deep Energy Retrofit

As we launched into work on this house it was difficult to estimate how much it would cost to carry out the project. We planned to do the work in stages so that we had a good idea of how much it was going to cost for each step in advance. The work would proceed step by step as availability of construction resources and our funding would allow. The first step was to deal with the basement as discussed above.
Notice the silt and clay layers – Winnipeg is in an ancient river valley.

The old cast iron sewer lines had to be replaced completely. Condensate from the furnace had been drained under the floor slab and corroded the sump that had been located above the open elbow you see below.

With the old gone and out of the way, the next step was to insulate and then pour the new floor. Note the thermal bridge between the old walls and foundation provided by rigid XP foam.

The new concrete floor was poured in place on top of 8 inches of XP foam, Poly vapour barrier, and new sewer lines plus weeping tile buried at the bottom. Note the new sump pit near the foot of the ladders. This completed the major work inside the house.

The next step was to strip the shingles from the roof, stucco from the exterior walls of the house and sheath the whole building with plywood on the walls and OSB on the roof. Twenty four inch roof trusses were placed on top of the OSB and steel roofing installed providing overhang as per the design.

With this weather barrier in place, work could proceed on the exterior of the foundation walls. This included blueskin on the sealed surface of the concrete walls and the top of the exposed footing. The weeping tile around the footing was replaced along with clean drainage rock.

The walls were then sheathed with eight inches of XP foam, poly air/water barrier and a protective layer of pressure treated plywood below grade. An exterior glycol loop was installed on top of an insulated skirt on top of the foundation before backfilling.

This completed work on the exterior walls extending from the lower edge of the footing up to the rim joist around the first floor of the house.

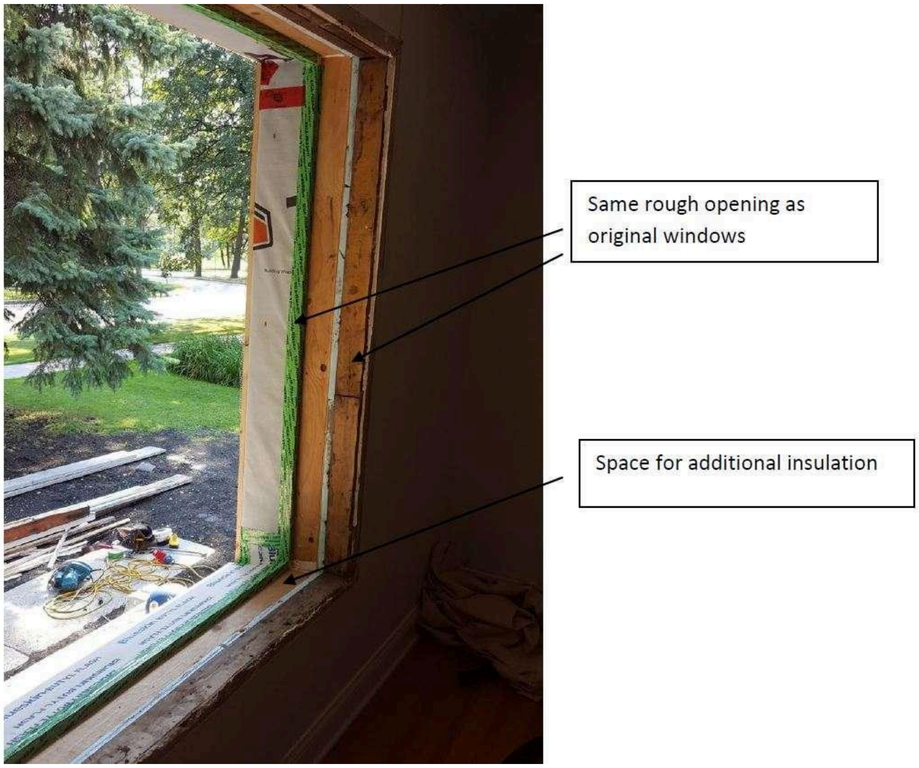
Then came the construction of exterior Larsen Truss walls extending from below the level of the rim joist up into the base of the roof. The following picture provides an overview of the truss structure, typical structural details around the doors, windows and the intersection with foundation insulation.

Design of the window installation and wall assembly was supported through the use of THERM modeling techniques to maximize thermal performance. Design performance of the wall assembly (old plus new) from the perspective of vapour permeability was evaluated using the WUFI software.

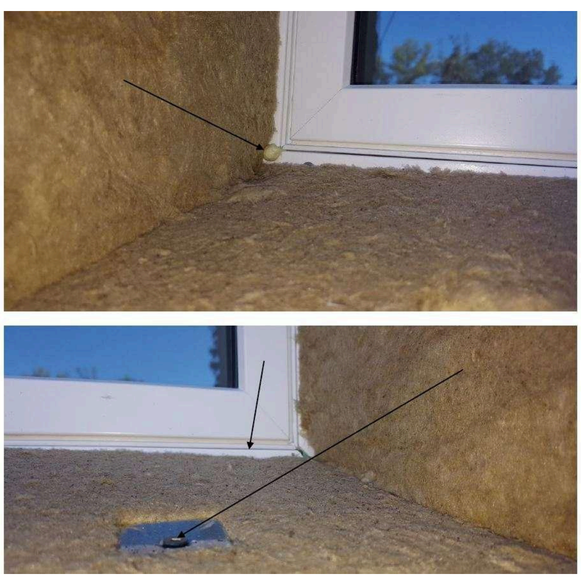
Existing doors and windows were left in place as we were living in the house throughout the construction process. The exterior chord of the trusses was then covered by sheathing and prepared for stucco as shown in the next pictures.

The Larsen Truss cavities were then filled with dense-pack cellulose. Areas under the windows were filled first through access holes that were later sealed (see red tape in the picture). The cavities were then filled and packed with cellulose working from the roof-truss cavities (see the supply hose going up through the eave near the service entrance).

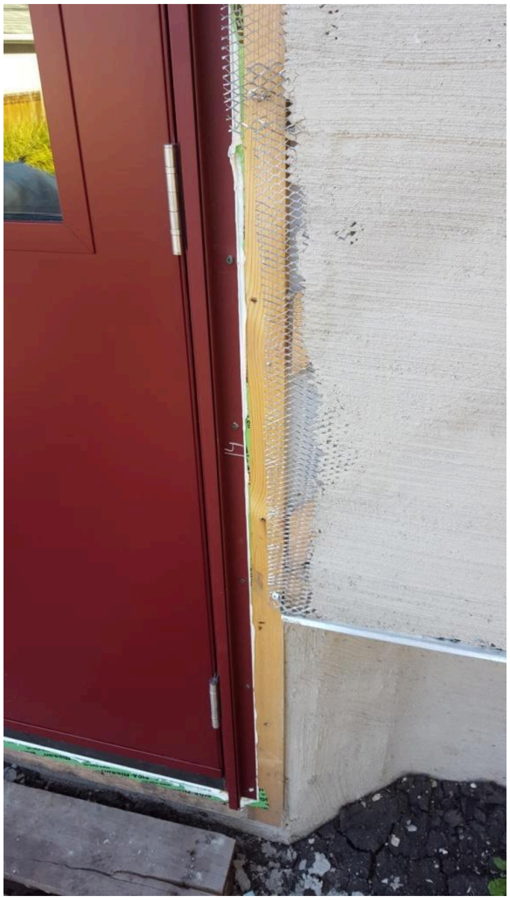
Now the new windows and doors could be installed to complete the insulated and vapour sealed shell of the house.



The exterior reveal of the windows could then be “over-insulated” with Roxul and prepared for stucco.



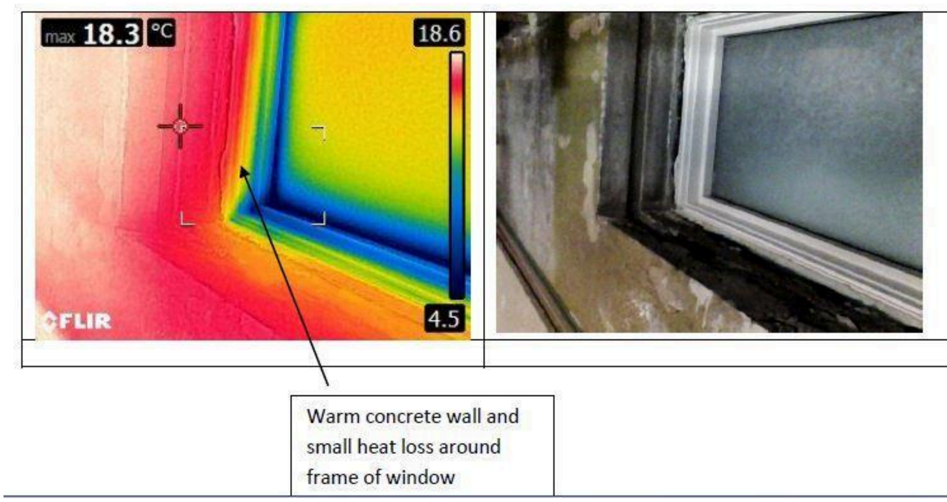
The doors had been fitted with fibreglass sills and the space between the new sill and the existing interior doors was temporarily filled with rigid insulation and rubber floor mat.

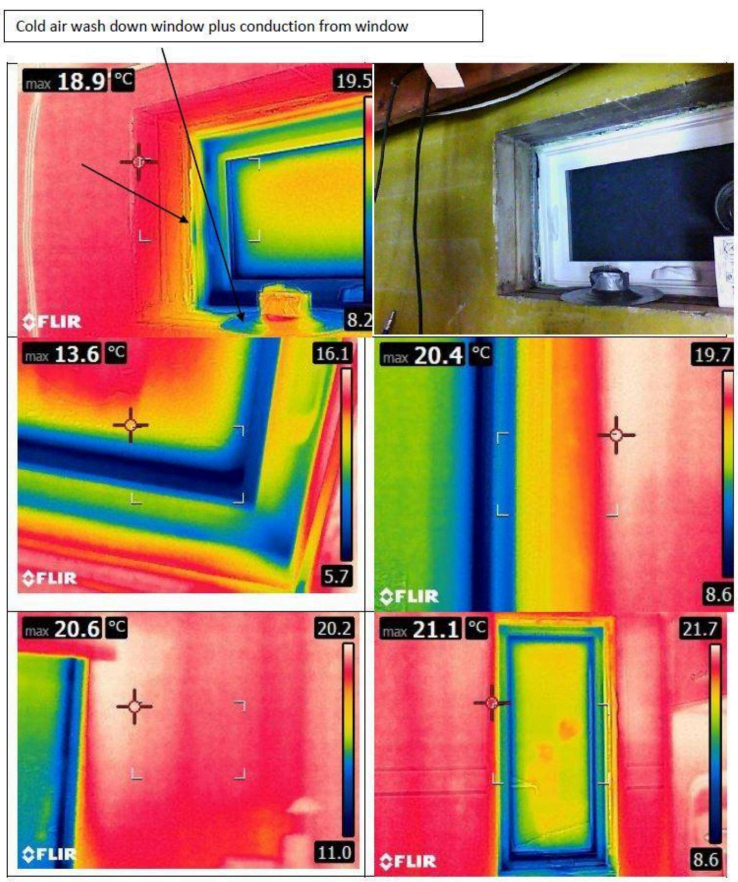


The base coats of stucco were applied late in the fall before first frost.

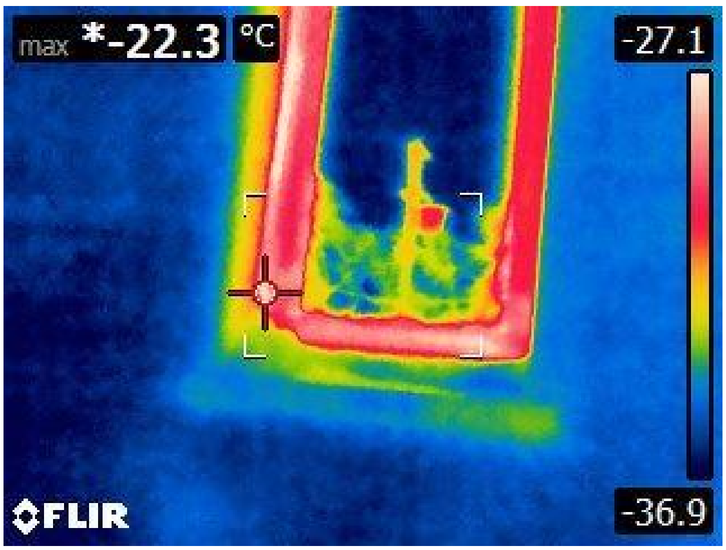
Winter soon settled in and provided the opportunity to get a visual test of the performance of the windows and window installations. Even though temperatures had dropped down to about minus 40 degrees C at the time, interior concrete wall temperatures remained at about 18 degrees C with very little heat loss around the perimeter of the windows. The majority of heat loss was through the area of the frame and edge of glass. (Note the temperature at the top left of each IR frame corresponds to the cross-hair location in the picture).

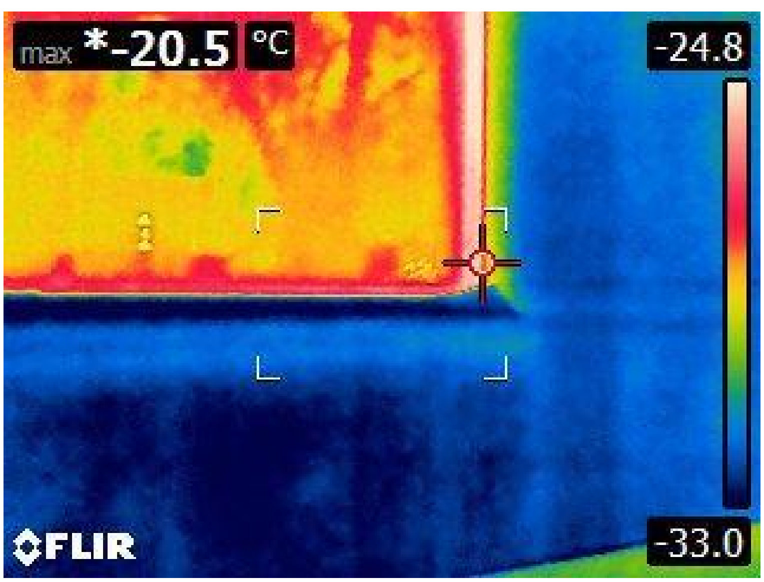
Performance Evaluation with Infrared Camera





It is interesting to note that triple-pane glass is a much better insulator than you might think – contrary to what you might expect it is better to keep the glass area as high as possible in a door to maximize insulation value and minimize heat loss (see bottom right hand frame in the picture above). The foregoing set of pictures were taken inside the house, the following pictures were taken from the outside.
Additional pictures at other locations around the house confirmed that the performance of the walls as well as the windows and doors was very good. Clearly the weakest links in the envelope are around the windows and doors exactly as had been predicted by PHPP and THERM analyses. The moral of the story is – keep the combination of frame area small and insulation value as high as is practical in these areas.





Where Are We Now

Somewhere during this process we disconnected from the natural gas utility service and have eliminated this component of carbon consumption. PHPP analyses, though not fully completed, indicated that our maximum heating requirement should be approximately 2800 watts in the dead of winter. So we replaced the former gas consumption with 3000 watts of baseboard heaters. This proved to be more than adequate during the winter of 2016/17. We are also installing 2000 watts of duct heater in the fresh air supply duct from the HRV – this heater will be controlled by a wall mounted thermostat and will eliminate the need to manually adjust baseboard heaters from time to time when weather changes. These two heat sources provide backup should one or the other fail.

It should be noted that our electricity is virtually all supplied by hydroelectric power – so it is green and is currently supplied at very attractive rates. However few good things last forever – privatisation of our utility company would inevitably raise costs to the consumer. So we have provided purlins in the roof to support enough solar panels to achieve close to net zero performance. In the event of utility power outages, if necessary we can connect a small gasoline powered generator to a generator sub-panel we have already installed and which has been wired to supply all critical services in the house.

A passive pre-conditioner has been installed that uses a glycol loop installed around the foundation of the house for two purposes. One is to warm up extremely cold fresh air as it is entering the home in the winter, and the second is to cool down warm/hot fresh air entering the home in the summer. At the cost of operating a very low power circulating pump a significant heating and cooling capability is available.

Fresh air to the house is provided by an HRV supplied by vanEE. The performance of the G2400H ECM machine is anticipated to work very well. It has the attractive features of very good cold weather performance, the ability to re-circulate air within the house during very cold or very hot weather, as well as high performance ECM fan motors that are both quiet and efficient. In addition, the control system offers a SMART mode that alters operation of the HRV based upon combinations of incoming fresh air temperature and the relative humidity inside the home. This mode of operation should work very well in our environment and has proven effective during the initial period of use.

Blower door tests, for both pressurization and de-pressurization at 50 Pa, have been carried out resulting in an average value of approximately 0.3 ACH. This is approximately half of the maximum allowed under the Passive House standard. This is a fantastic achievement for a retrofit house and a good indicator of great attention to detail by the contractor.

In order to support the possible desire to have the home certified as a Passive House Retrofit, some thirty or so temperature sensors have been installed in the exterior walls, around the HRV, and in several locations within the home to monitor and control operation. The pump for the pre-conditioner is controlled by a simple algorithm driven by a handful of these measurements. Data from these sensors will be logged along with corresponding weather data. Eventually we will establish guidelines for when and how to use the pre-conditioner in both the winter and the summer for maximum benefit.

With limited operation of systems in the house this last winter we can say that the house is and will be comfortable. There are no hot or cold spots in the house and interior temperature changes take place over days, not hours as in every other house we have experienced.

Our experience with the house this last summer, while work was still in progress, was that overheating was only a problem on the second floor when sun was pouring in the old south-west facing window. With installation of much better windows that provide both a better solar barrier and better night-time ventilation we do not anticipate overheating to be a problem. It is comforting to know that PHPP calculates little overheating when the HRV is used in by-pass mode to bring in cooler fresh air when it is available in the evenings. Resilience may be required if forecasted heating of our environment is experienced. If these techniques prove to be inadequate we have considered the installation of a currently available high performance air-to-air heat pump outside the house for the supply of either cooling or heating. Another alternative that may be available would be application of a very small air-to-glycol heat pump that utilizes the ground loop around the house as a heat source/sink.

We have not lived in the retrofit house for a full year so cannot tell you what our eventual annual power consumption is likely to be – but we do have a rough indication from a few months this winter. From the first meter reading after it turned cold (14 November 2016) through to 01 March 2017 total electrical power consumption was 4391 kWh. Equivalent PHPP calculated consumption is approximately 4604 kWh of which 3206 kWh would be direct heating requirement. Subjectively we know the consumption should have been higher if the HRV had been functioning throughout this period and if we had been operating the house at the design temperature of 20 degrees C. In any case, we believe the performance of our house will turn out to be very near to that predicted by PHPP. A couple of years of utility meter records will be required to confirm this along with related meteorological records and measured temperatures from our house.

Summary

Have we achieved all our objectives? We believe we have gone as far in this direction as is practical. Most of our criteria for success have been met, only time will tell if we got the balance right. The costs are not all in, but neither are the benefits – we are happy with interim results.

Do we have a “green” house? That is subject to a lot of judgement but we believe we do.
Do we have a Net Zero Energy Ready house? We believe this can be achieved if desired in the future.
Do we have a Passive House? According to current PHPP analyses we should meet the EnerPHit Standard.
How about LEED for Homes? We have no expertise in this area but suspect that we may have met these requirements.

Acknowledgements

We stand on the shoulders of many. Thanks to John Larsen who started this revolution many years ago. Thanks to Wolfgang Feist and many working with him at Passive House International who were inspired by Larsen and others before them. Thanks specifically to the management and crew of Sun Certified Builders Cooperative who have adapted this knowledge to our environment in Manitoba. It really can be simple but surely is all about the details.